

THE NATURE OF X-RAY ABSORBED STARBURST QSOs AND THE QSO EVOLUTIONARY SCHEME

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ABSTRACT

In contradiction to the simple AGN unification schemes, there exists a significant population of broad line, $z \sim 2$ QSOs which have heavily absorbed X-ray spectra. These objects have luminosities and redshifts characteristic of the sources that produce the bulk of the QSO luminosity in the universe. Our follow up observations in the submillimetre show that these QSOs are embedded in ultraluminous starburst galaxies, unlike most unabsorbed QSOs at the same redshifts and luminosities. The radically different star formation properties between the absorbed and unabsorbed QSOs implies that the X-ray absorption is unrelated to the torus invoked in AGN unification schemes. The most puzzling question about these objects is the nature of the X-ray absorber. We present our study of the X-ray absorbers based on deep (50–100ks) XMM-Newton spectroscopy. The hypothesis of a normal QSO continuum, coupled with a neutral absorber is strongly rejected. We consider the alternative hypotheses for the absorber, originating either in the QSO or in the surrounding starburst. Finally we discuss the implications for QSO/host galaxy formation, in terms of an evolutionary sequence of star formation and black hole growth. We propose that both processes occur simultaneously in the gas-and-dust-rich heavily obscured centres of young galaxies, and that absorbed QSOs form a transitional stage, between the main obscured growth phase, and the luminous QSO.

Key words: X-rays; submillimetre; galaxies: active.

1. INTRODUCTION

The prevalence of black holes in present day galaxy bulges, and the proportionality between black hole and spheroid mass (Merriitt & Ferrarese, 2001) implies that the formation of the two components are intimately linked. One way to probe star formation in distant QSOs is to observe them at submillimetre wavelengths, and so measure the amount of radiation from young stars which

is absorbed and re-emitted by dust in the far infrared. With this in mind, we have observed matched samples of X-ray absorbed and unabsorbed QSOs at $850\mu\text{m}$ with SCUBA. These observations revealed a remarkable dichotomy in the submillimetre properties of these two groups of sources: X-ray absorbed QSOs are often ultraluminous infrared galaxies, while X-ray unabsorbed QSOs are not. This suggests that the two types are linked by an evolutionary sequence, whereby the QSO emerges at the end of the main star-forming phase of a massive galaxy (Page et al., 2004; Stevens et al., 2005, Carrera et al. 2006, this volume).

However, the nature of the X-ray absorption remains puzzling. It could be due to gas located within the AGN structure, or from more distant material in the host galaxy. These objects are characterised by hard, absorbed X-ray spectra, but they have optical/UV spectra which are typical for QSOs, with broad emission lines and blue continua. Assuming that their hard X-ray spectral shapes result from photoelectric absorption from cold material with solar abundances, the column densities are $\sim 10^{22} \text{ cm}^{-2}$. These properties are surprising: for a Galactic gas/dust ratio, the restframe ultraviolet spectra would be heavily attenuated by such large columns of material. Therefore in order to investigate the X-ray absorption, we have obtained deep (50–100ks) XMM-Newton observations of three submillimetre bright, X-ray absorbed QSOs from our sample of hard-spectrum *Rosat* sources (Page, Mittaz & Carrera, 2001).

2. RESULTS

The XMM-Newton spectra were first fitted with a power law and fixed Galactic absorption. Surprisingly, the power law produces reasonable χ^2 values. However, the photon indices are unusually hard for QSOs, and the data show a deficit of counts relative to the model at the softest energies, indicating that absorption is present. The original *Rosat* PSPC spectra and the XMM-Newton spectra show excellent agreement (see Fig. 1).

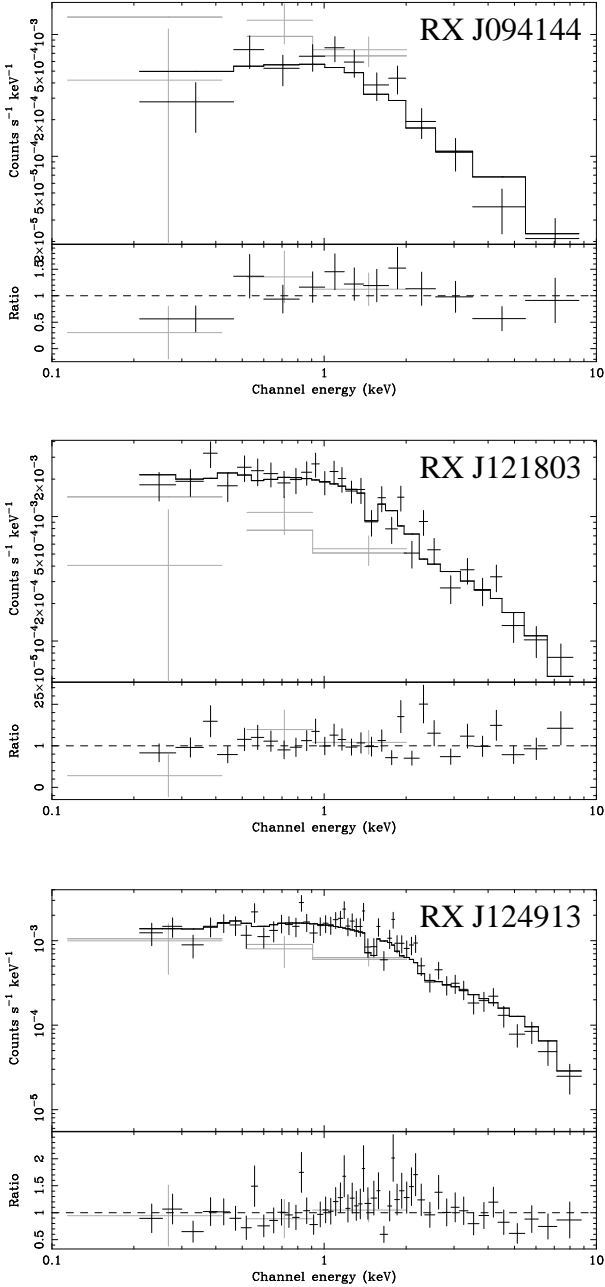


Figure 1. XMM-Newton EPIC spectra (black) and Rosat PSPC spectra (grey) of three X-ray absorbed QSOs. The model is a simple power law with fixed Galactic absorption. The best-fit power law photon indices Γ are 1.3 ± 0.1 , 1.4 ± 0.1 and 1.4 ± 0.1 for RX J094144, RX J121803, and RX J124913 respectively. Such photon indices are unusually hard for radio-quiet AGN. In all three objects there is a deficit of counts at the lowest energy, indicating that absorption is responsible for the hard spectral shape; this is also seen in the Rosat data. Furthermore, RX J094144 and RX J124913 show some systematic curvature relative to the power law model.

The hypothesis of a normal ($\Gamma = 2$) AGN X-ray spectrum and a cold absorber is strongly rejected for RXJ121803 and RXJ124913. Therefore we considered ionised absorber models for the X-ray absorption, using the ‘xabs’ model in SPEX, which includes both photoelectric and line absorption. For all three AGN an acceptable fit can be obtained with a $\Gamma = 2$ power law and an absorber with an ionisation parameter $\log \xi \sim 2$ and column densities of $10^{22.5}$ – $10^{23.5}$ cm^{-2} . These absorbers have similar properties to the high-ionisation absorber phases seen as outflows in some nearby Seyfert 1 galaxies and QSOs such as NGC3783 and PG1114+445 (Ashton et al., 2004).

At these ionisation parameters and column densities, the absorbers are likely to originate in the AGN themselves, rather than in the host galaxies. This solution is attractive, because it is compatible with the lack of optical extinction in these objects: if the absorber is driven as a wind, either from the accretion disc or from evaporation of the inner edge of the molecular torus, then dust will be sublimated before (or as) it enters the flow.

3. IMPLICATIONS FOR AGN AND GALAXY EVOLUTION

The low space density of X-ray absorbed QSOs relative to unabsorbed QSOs and to distant ultraluminous galaxies detected in blank field SCUBA surveys, implies that the X-ray absorbed QSOs are caught during a short-lived transitional phase. Before this brief phase, AGN must be weak, and heavily obscured (Alexander et al., 2005); after this phase the host galaxy is essentially fully formed, and the naked QSO shines brightly until its fuel is consumed. A number of theoretical models predict a very similar evolutionary pattern. In many of these models, the QSO terminates the star formation in the host galaxy by driving a powerful wind (e.g. Fabian, 1999; Di Matteo Springel & Hernquist, 2005). The EPIC spectra of our X-ray absorbed QSOs suggest that the absorbers are ionised winds driven by the AGN, and therefore that the transition between buried AGN and naked QSO is mediated by a radiatively driven wind from the AGN, as predicted by these models.

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